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PETROGRAPHY OF SEDIMENTARY ROCKS FROM THE TORQUAY-EASTERN VIEW AREA, VICTORIA

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In the course of the detailed investigation of measured sections in the Torquay-Eastern View area by Dr. Raggatt and Miss Crespin (1954), rock specimens were submitted for petrographical determination. This short paper gives the result of this examination. The numbers of samples, such as BR.5 and EV.3, refer to those given by Raggatt and Crespin in their Sections 7 and 23.

White Rock from near top of Addiscot Member, collected from western end of Demon's Bluff cliffs, east side of Anglesea River

Most of this specimen is very fine-grained — average grain size 0·005 to 0·0025 mm. It contains a few quartz grains of average diameter 0·1 mm., and also a little clay. Its specific gravity is 2·58. Excepting the clay and quartz, the rock is soluble in hot sulphuric acid; from the solution aluminium hydroxide was precipitated by adding ammonium hydroxide. The greater part of the rock is soluble in caustic soda solution also. Water is given off on heating in the closed tube. The refractive index of the soluble material is about 1·557.

These tests indicate that the soluble mineral is gibbsite. The low double refraction (too low for gibbsite), as observed in thin section, is due to the extremely fine grain-size of the mineral. Gibbsite has a specific gravity of 2·35±; the figure 2·58 is high, but would probably be accounted for by the impurities mentioned, and by any boehmite (S.G. 3·01 - 3·11) which may be present in a rock of this kind, but was not actually determined.

A mottled yellowish grey (5Y7/2)* and dark grey (N3) substance, which borders and marginally penetrates the gibbsite as veinlets, was also examined, and was found to consist essentially of montmorillonite containing irregularly distributed angular grains of quartz (average grain-size 0·1 mm.), which may occupy up to 35 per cent by volume of this part of the rock. Minor constituents are fragments of felsite or chert, black iron-ore, leucoxene, zircon, and rutile. The montmorillonite is patchily and lightly stained by limonite, and generally has aggregate polarization.

Refractive index measurements, which formed the basis of the determination of the montmorillonite, yielded the following results:

(i) Yellowish grey material .. .. .. 1·515±
(ii) Dark grey material .. .. 1·500±

These figures lie within the ranges recorded for different types of montmorillonite.

Bright green material (glauconite (?)) from the top of the Jan Juc Formation (B R.5), Bird Rock Point

In the hand specimen, this material is coloured dusky green (5G3/2), and has a somewhat velvety appearance. Nests of minute octahedra of pyrite are present in small hollows and open cracks and, to a lesser extent, in the body of the rock.

* Colours recorded are as defined in the "Rock-Color Chart" of the National Research Council, Washington, D.C.

Measurements with immersion media showed that the mean refractive index of the green mineral is approximately 1·560; this figure is very much below the lower limit of the range usually stated for the mean index of glauconite, viz. 1·609 to 1·643, and is close to those recorded by Dallwitz (1952, p. 55) for glauconite from Maslin Bay, South Australia; it is also lower than the actual limits (1·575 to 1·602) found by Glover (1954) in glauconite from rocks of the Torquay-Airey's Inlet area. These discrepancies suggest that chemical and optical work should be done to establish the full ranges of composition and optical properties of the group of minerals broadly classed as glauconite; such work may also throw light on the origin of different types of glauconite, and on the conditions of sedimentation and diagenesis which may be responsible for the differences.

In thin section the glauconite is coloured bright yellow green, and has embedded in it scattered quartz grains, shell fragments and foraminiferal tests, and rare pyrite, all of which make up not more than 5 per cent of the whole rock. The chambers of the foraminifera are filled with glauconite. Some of the glauconite is coarse-grained; one area which extinguishes as a unit measures 2·5 mm. x 2·5 mm.

Part of the specimen could not be successfully sectioned. On crushing, this was found to consist of quartz, shell fragments, glauconite, foraminiferal tests partly or wholly filled with glauconite, and claystone.

It is probable that the glauconite in this rock has been derived from clay. No clay remains in the sectioned part of the specimen, but some was observed in crushed material from another part of the rock. (See above.)

Concretions in top of Jan Juc Formation (B R.5) at Bird Rock Point

The sample is a friable, clastic rock, consisting of two distinct parts. One part, which may be considered as the matrix of the other, is coloured very light olive green (5Y7/1), and consists of shell fragments, shells, quartz grains, and glauconite. The other part (the "concretions") is composed of light olive grey (5Y6/1) claystone containing shell fragments, shells, and a high percentage of somewhat irregularly distributed glauconite; small scattered crystals and grains of pyrite can be identified with the aid of a lens. Where the claystone contains no glauconite, it has conspicuous shrinkage cracks. The glauconite ranges in colour from greyish-green (10GY5/2) to dusky yellow green (5GY5/2).

The mutual relationships of the two parts of the rock cannot be conclusively determined from the sample. However, it appears probable that the more argillaceous glauconite-rich masses have been laid down as infillings of the troughs of water-current ripple marks preserved in a less argillaceous rock. Certain environmental conditions implied by the presence of ripple marks are consistent with those under which some authors consider many glauconitic rocks to have been formed (Lochman, 1949, p. 56; Imlay, 1949, pp. 90-91).

The "matrix" is composed of shell fragments, clay which is mostly bonded by calcite, quartz grains, glauconite, and foraminiferal tests. Microscopically, it is impossible to estimate, even approximately, the ratio of carbonate to clay; however, it is clear that the percentage of clay is very much less than that of carbonate. The quartz grains are angular, and have an average size of 0·07 mm.; they make up 15 to 20 per cent of the rock. Glauconite is present to the extent of about 3 per cent. Most of it belongs to Glover's first class—that is, it is or was included in tests of organisms, particularly gastropods, foraminifera, and parts of echinoid plates. In some cases only the outer chambers of foraminifera contain glauconite, and, in fact, most of the foraminiferal tests are free from this mineral. Only a few of the broken echinoid plates contain glauconite, and mostly only a group of pores

in any one plate fragment is filled with glauconite. Some of the glauconite falls into Glover's second class; generally, this glauconite takes the form of oval to semi-oval and irregular masses with sharp boundaries, and appears not to have been enclosed within tests of organisms at any time. In addition, a few oval grains ((?) coprolitic mud) show only incipient glauconization, a stage in which a strong overall tinge of green has been imparted to the originally brown grain. Finally, a little of the glauconite has "indefinite boundaries" which appear to grade imperceptibly into the surrounding argillaceous and calcareous material (Glover, 1954, p. 154).

Accessory minerals—black iron-ore, pyrite and zircon—are very rare in this part of the rock.

The "matrix" is a clayey, sandy and shelly calcareous calcarenite, containing a small percentage of glauconite.

The glauconite-rich rock associated with that described above differs from it in the following ways:

(i) Quartz is less plentiful—it makes up 5 to 7 per cent of the rock, as compared with 15 to 20 per cent in the "matrix".

(ii) Clay is much more plentiful, and a high proportion of it is not bonded by calcite.

(iii) Glauconite is an important component. It is irregularly distributed, and makes up about 15 per cent of the rock.

Thus the major constituents of this part of the rock are calcite (as broken and unbroken shells), clay, glauconite and quartz, in order of decreasing abundance. Accessory minerals are quite rare, and consist of pyrite, black iron-ore, probable marcasite, and fine flakes of muscovite. The rock is a clayey, glauconitic, and silty calcareous calcarenite, containing numerous shells and shell fragments.

Recognizable shell fragments and complete skeletons comprise lamellibranchs, foraminifera, gastropods, echinoids (parts of plates and spines), and bryozoa. Perforated or ornamented spherules or cylinders of calcite, representing organisms or parts of organisms, are conspicuous in some places, but occupy probably less than 0·1 per cent by volume of the rock.

The pyrite, which occurs as irregular grains, cubes and octahedra, is generally enclosed in or closely associated with glauconite; it is commonly bordered by black iron-ore, separate grains of which are also scattered through the rock. The (?)marcasite is found as aggregates or strings of minute grains embedded in the clayey, calcareous cement. The black iron-ore which is associated with the (?)marcasite is more abundant in some parts of the rock than in others.

Glauconite occurs in all of the ways previously described for the "matrix", but dominantly as sharp-bordered oval and irregular grains, as distinct from infillings of shells. It appears to have been derived from clay or from coprolitic pellets, and its abundance is a reflection of the abundance of clay in this part of the rock, as compared with the "matrix". The predominance of this type of glauconite lends support to the idea that mud is commonly the progenitor of this material.

In some places bodies of glauconite simply grade outwards, by decrease of that mineral, into the surrounding clay; in other places clay is only lightly impregnated with glauconite. Both of these modes of occurrence are essentially the same, and they strongly suggest that the glauconite has been derived directly from clay.

Many of the probable coprolitic pellets that have been converted to glauconite contain minute grains of quartz (see Figs. 4, 5 and 7, Takahashi and Yagi, 1929, p. 845).

Some of the glauconite which occurs in the tests or organisms does not completely fill them, but appears to have shrunk away from the walls; this condition is particularly conspicuous where the mineral is contained in the openings of a bryozoal skeleton. In some places the tests are partially broken and/or dissolved, but the original shape of the enclosed glauconite masses is retained.

All the glauconite shows aggregate polarization. Its refractive indices are lower than those usually recorded, and differ from one mass to another. Most aggregates have a R.I. of about 1·565, but some fall below 1·560, and others range above 1·570. This apparent lack of constancy in composition would make definitive chemical and optical work on such a sample very difficult, but would still allow significant generalized data to be obtained.

Specimen from Great Ocean Road, ½ mile west of Painkalac Creek (Airey's River) Bridge—EV.3

This is a friable, mottled rock with the texture of a claystone; it is externally and internally traversed by a network of shrinkage cracks. The principal colours giving rise to the mottling are moderate red (5R4.5/4) and dark red (5R4/4). Another prominent colour is pale yellowish grey (5Y7.5/2), but this appears mainly in one band; scattered pale greyish yellow (5Y8.5/4) flecks are also present.

Microscopically, the rock is found to consist of a fine-grained, dark yellowish brown (10YR4.5/2) matrix in which are embedded very irregularly shaped fragments of devitrified glass and angular fragments of quartz.

The matrix is volcanic ash. It is invariably darker than average in a zone about 0·025 mm. wide round the borders of the glass fragments. Differences in concentration of clots and disseminated particles of haematite in the matrix impart the mottling to the hand specimen.

The outlines of the glass fragments are extremely ragged, as would be expected in a tuff. Their average size is about 0·3 mm., and the largest measures 1·25 mm. Quartz grains are included in some of the fragments.

In the slide examined the dimensions of the quartz grains range between 1·75 mm. and 0·01 mm., but most are about 0·3 mm. across. Shattering in a few grains confirms the suggested explosive volcanic origin of the rock. Felspar may have been present, but if so, it is now so much altered that it can no longer be distinguished.

Single grains each of zircon and tourmaline are the only accessories noted.

The estimated percentages of the major constituents are: haematite-stained ash 67, devitrified glass 19, and quartz 14.

The rock is an acid ashstone containing fragments of devitrified glass and of quartz.

Anglesea Member — Type locality

The specimen is a fine-grained, clastic, friable and coarsely mottled rock whose colouring ranges between dusky yellowish brown (10YR2/2) and light yellowish brown (10YR5/2). Bedding is not prominent; where visible it is in the form of discontinuous bands of different colour from 1 mm. to about 1 cm. thick, and showing evidence of current action. Only scattered flakes of muscovite can be conclusively identified with the aid of a lens.

On strong heating the rock is bleached and gives off an odour of burning coal.

For microscopic examination the darkest part of the rock was sectioned.

Quartz is the dominant mineral. Very few of the grains are rounded; most are angular, some are splintery, and a few subangular. Their grain-size is fairly uniform, and averages 0·05 mm.

The quartz grains are set in a matrix of carbonaceous clay. This matrix may occur interstitially between the quartz grains, or as irregular clots and bands containing a few grains of quartz, sericite, chlorite, marcasite, and felsitic igneous rock or chert; the size of these included grains ranges from 0·05 mm. down to 0·005 mm. or less. In colour the carbonaceous clay ranges between very dark orange brown (10YR3/6) and dusky orange brown (10YR2/6), according to the degree of concentration of carbonaceous matter. The clay has probably been derived from a vegetable slime. Small irregular bands and clots of brown coal represent strong concentrations of carbonaceous matter.

Unevenly distributed through the rock are fragments of a chloritic mineral, possibly altered and leached chamosite, occurring in grains of about the same size as those of quartz. This mineral is length slow and biaxial negative with low optic axial angle; it has micaceous cleavage and straight extinction, may be faintly pleochroic, and has a double refraction of approximately 0·005. In colour it ranges between pale greyish yellow (5Y8.5) and dusky yellow (5Y6/4); these differences may be partly due to staining by organic material. Some grains show aggregate polarizatin.

Minor constituents, approximately in order of decreasing abundance, are chert or fragments of felsite, marcasite, muscovite, leucoxene, felspar (acid plagioclase, orthoclase, and microline), brown and green tourmaline, zircon, very rare glauconite, ilmenite, monazite, and (?)cassiterite. The last three minerals were found in the residue obtained by panning.

The sectioned portion of the rock consists of an estimated 50 per cent quartz, 38 per cent clayey and carbonaceous cement, 5 per cent chlorite, 2 per cent (?)chert, and 5 per cent other constituents, and is a clayey, carbonaceous greywacke-siltstone.

(It is to be noted that, in describing the colour of the matrix of this rock, the colour names "very dark orange brown" and "dusky orange brown" are used. These colours do not appear on the colour chart, and so the above colours and their names were chosen more or less by guesswork. The colour name "pale greyish yellow" for the chloritic mineral was arrived at in a similar way.)

Addiscot Member — Demon's Bluff cliffs

The sample is a friable, non-bedded, medium-grained clastic rock, in which, in the hand specimen, only scattered flakes of muscovite can be identified. In one area small dark clots, apparently rich in carbonaceous material, are visible. The colour of the rock is very pale yellowish brown (10YR7/2).

Microscopically the rock is seen to consist essentially of even-grained quartz grains in a matrix of clay.

The quartz grains are angular to sub-angular, and a few are splintery. Their average grain-size is 0·07 mm.

The clay is unevenly distributed, and is irregularly, though lightly, stained by limonite.

Other constituents of the rock are rounded fragments of felsite or chert, leucoxene, ilmenite, brown and green tourmaline, chlorite, muscovite, felspar (acid plagioclase, orthoclase, and microline), zircon, rare granular limonite, and very rare epidote and probable glauconite. In a dish concentrate rutile and a little monazite were found in addition; this concentrate also revealed some perfect, water-

clear, doubly-terminated crystals of zircon, which may have formed during diagenesis. No carbonate was noted in the slide, but slight effervescence took place when the rock was attacked with cold dilute HCl, and further effervescence occurred in hot concentrated HCl.

The rock consists of about 55 per cent quartz, 38 per cent limonite-stained clay, and 7 per cent other minerals, and is a very fine quartz-clay greywacke.

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